CHE1103ID: History of Chemistry

Unit 1

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Old Traditions of Chemical Sciences: Ancient Chemical Technologies

The use of chemical processes to manipulate matter dates back to prehistory. One of the first major milestones was the taming of fire, with evidence of campfires as early as 500,000 BCE. The habitual use of fire appears around 400,000-300,000 BCE and becomes common after 100,000 BCE. Use of fire led to many technologies. Some major chemical technologies practiced in ancient times in different regions of the world are discussed below:

1. Cooking

   Initially, humans could sustain fire rather than start it deliberately. Fire was used for warmth and light and eventually for cooking. Cooking is considered the earliest form of chemical technology (Table 1). Cooking meat made it tender, tastier, and safer by killing bacteria and parasites. It also made food easier to digest by breaking down proteins and carbohydrates.

2. Mineral Pigments

   Another early chemical technology was grinding colored minerals to create powdered pigments. These pigments were used for cave paintings and as cosmetics for the body and face. The oxides and sulphides of arsenic and antimony were used as pigments. The red oxide of iron was used in the decoration of cave walls. Copper minerals were used as cosmetics.

Table 1. Chronological List of Common Chemical Technologies in ancient time

Technology	Time period of period
Cooking	ca. 300,000 BCE
Mineral pigments	pre-30,000 BCE
Pottery	ca. 18,000 BCE
Fermented beverages	10,000-8000 BCE
Smelting and metalworking	ca. 6000 BCE
Cloth and fabrics	ca. 6000 BCE
Tanning hides and leather	4500-2000 BCE
Organic dyes	ca. 3000 BCE
Scented oils and perfumes	ca. 3000 BCE
Soap	ca. 3000 BCE
Synthetic glass	3000-2500 BCE

3. Food preservation

   Natron, an impure form of common salt extracted from dry lakes or from evaporation of Nile river water was used in Egypt and former lands of Persia and Mesopotamia for embalming and preservation of food.

4. Pottery

   By 30,000 BCE, humans had mastered fire and began using it for pyrotechnology beyond cooking. The earliest such technology was pottery, developed around 18,000 BCE by firing clays and alumina-silicates. Pottery became a primary material for storage, cooking, and transportation of food for the next 15-20 millennia.

5. Fermentation

   With the availability of reliable containers, humans discovered that sugar-rich solutions stored in them could ferment into alcoholic beverages. This likely began between 10,000-8000 BCE, resulting in drinks like mead, palm wine, beer, and grape wine.

6. Smelting and Metalworking

   By 6000 BCE, humans learned to extract metals from ores, starting with copper smelting. This led to a wide range of tools, ornaments, and vessels. Later, adding tin or zinc to copper created harder, more durable alloys like bronze and brass.

7. Bitumen products

   Existence of exposed bitumen in Mesopotamia led to the creation of crude asphalt obtained by mixing the naturally found tar with chalk, sand and gravels. Asphalt was an efficient sealant and mortar for housing and boat building.

8. Plaster production

   Plaster was produced from gypsum or limestone. Plaster was then used to make large blocks for building purposes.

9. Organic-Based Chemical Technologies

   The period of metal introduction also saw the development of new technologies involving organic materials. These included processing plants to make fabrics like linen, tanning hides into leather, isolating organic dyes for coloring, producing scented oils and perfumes, and making soap.

10. Synthetic Glass

    Unlike natural glass like obsidian, synthetic glass was made from silica sources and dates back to no later than 3000 BCE. Molten glass could be shaped and retained its form upon cooling, much like modern plastics. It complemented other structural materials like pottery and metal.

Metal extraction in the ancient times

- First use of metals

The first metals used by humans were copper and gold. These metals were likely to found in their natural forms as nuggets. Their distinct reddish (copper) or yellowish (gold) colors and shiny metallic luster would have attracted early humans. Unlike other materials, copper and gold are malleable, meaning they can be hammered into different shapes without breaking. This property allowed early humans to fashion these metals into ornaments, which was likely their first use.

- Extraction of copper

Copper's usefulness became more evident when it was discovered that it could be beaten into sharp edges, making it more effective than stone tools. However, because natural copper was rare, its use for tools was limited initially. Over time, people discovered that copper could be extracted from certain types of rocks, which made it more widely available. The process of obtaining a metal from its ore (rock) by heating and melting is called smelting. Smelting began around 4000 BCE, possibly in the *Sinai Peninsula* or the region of modern-day Iran. With this new ability to produce copper, it became common for tools, especially in advanced civilizations like Egypt.

- The Bronze Age: Discovery of Bronze

Around 3000 BCE, an accidental discovery changed the course of metalworking: the creation of bronze, an alloy made by heating copper ores with tin ores. This new metal was harder and more durable than pure copper, making it ideal for tools, weapons, and armor. By 2000 BCE, bronze was widely used, and it marked a new era known as the Bronze Age.

During this period, warriors in many cultures, including those involved in the famous Trojan War, used bronze weapons and armor. Metalworkers who could produce high-quality bronze tools and weapons were highly valued, much like modern-day scientists.

- The Iron Age: Discovery of Iron and Steel

Even during the Bronze Age, people were aware of a metal harder than bronze—iron. However, iron was rare because it was initially found only in meteorites. Unlike copper, extracting iron from its ores required much higher temperatures and better ventilation, which a simple wood fire could not provide. The secret to smelting iron was discovered around *1500 BCE in eastern Asia Minor by the Hittites*, who started using iron for tools and weapons.

Pure iron, known as wrought iron, is not very hard. However, when iron picks up carbon from charcoal during the smelting process, it forms steel, a much harder alloy that can maintain a sharper edge. This process, known as "steeling," was a significant advancement in iron metallurgy and marked the beginning of the Iron Age. Armies equipped with iron weapons and armor, such as the Assyrians around 900 BCE, gained a significant advantage over those using bronze.

Metal Extraction in Ancient India

For over 7,000 years, India has had a rich tradition of metalworking skills. The history of metal extraction in India can be understood through archaeological findings and ancient texts. Here is a brief overview of metal extraction in ancient India, focusing on different metals and the techniques used to extract and process them.

- Early Evidence of Metal Use

The earliest evidence of metal use in the Indian subcontinent comes from *Mehrgarh* in Baluchistan, where a small copper bead was found, dating back to about 6000 BCE. This copper was likely native copper, not extracted from ore. By the time of the Harappan civilization, metalworking skills had advanced significantly. Metalsmiths of the Harappan civilization (2600–1900 BCE) obtained copper ore from the Aravalli Hills and regions beyond, such as Baluchistan. They used various metals like tin, arsenic, lead, and antimony for alloying and perfected techniques such as wax casting to create bronze figurines and other objects.

- Copper Metallurgy

Copper metallurgy in India dates back to the Chalcolithic period (Copper Age). During this period, copper and bronze were widely used for making weapons, tools, and ornaments. Excavations at Mohenjodaro, one of the major Harappan sites, show that copper objects contained lead and nickel, indicating that Harappans were alloying metals to enhance their properties. Copper was smelted from ore and then refined in clay crucibles. Evidence of copper smelting has been found in many sites, such as *Ahar* near Udaipur in the Aravalli Hills. The copper ores in this region contained 4–8% arsenic, and many copper objects from Harappan sites show high levels of arsenic, suggesting that they sourced their ore from these hills. The metalworkers were skilled in extracting copper with a high purity of around 98%, similar to modern standards of blister copper.

- Iron Metallurgy

Excavations in the Ganges Valley and Vindhya Hills show that the art of iron smelting was well developed in eastern India around 1800 to 1000 BCE. Evidence of iron furnaces, artifacts, and slag layers has been found, dating back to this period. Indigenous tribes such as the *Agaria* in central India continued traditional iron smelting well into the modern era. Their primitive furnaces were well-designed, using pre-shaped curved clay bricks, and were almost as efficient as modern blast furnaces from the 1960s-70s. The ancient iron smelters in India had developed specialized skills in hot and cold forging and understood the effects of carbon on iron properties, leading to innovations like carburization, which resulted in steel making. Indian steel, especially *Wootz steel*, was highly regarded worldwide and exported to Europe, China, and the Arab world. The Wootz steel, known as *Damascus steel* in the Middle East, became famous for its strength and quality.

- Zinc Metallurgy

India was the first country to master the distillation of zinc. Zinc production was mainly concentrated in *Zawar*, Rajasthan, around the 6th or 5th century BCE. Due to zinc's low boiling point, it tends to vaporize during smelting, resulting in the loss of metal. To counter this, Indian metallurgists developed a unique downward distillation technique. In this method, zinc vapors produced in the upper part of a retort were condensed in a lower container cooled by water. This innovative technique allowed for the effective extraction of zinc. The same method was later applied to mercury distillation.

Ancient India had advanced knowledge of metal extraction and metallurgy. From copper and iron to zinc, Indian metallurgists developed innovative methods for extracting and refining metals, contributing significantly to the field of chemistry and material sciences.

Pigments and Dye

- Pigments in Ancient Art

Ancient humans used natural mineral pigments to create some of the earliest known paintings, which date back as far as 30,000 years. These paintings have been found in caves in southern France. The pigments they used were derived from naturally occurring minerals:

Red: Made from iron oxide.

Yellow: Created using iron carbonate.

Black: Produced from manganese dioxide or sometimes soot.

These natural pigments were ground into a fine powder and mixed with a binding agent like animal fat or water to create paint. The Egyptians later expanded their range of pigments by using chemically prepared substances. For example, they created red lead oxide by heating lead with basic lead carbonate. This chemical preparation marked an early attempt to produce more vibrant and lasting colors.

- Development of Dyes

The desire to color clothing led to the development of dyes, which were different from pigments because they chemically bonded with the fabric. Ancient people learned that to make a dye permanent (or "fast"), the fabric had to be treated with a substance called a mordant. Mordants help bind the dye to the cloth, making the color more durable. Alums, which occur naturally, were found to be excellent mordants, although those containing iron salts could cause unwanted colors in the dyeing process.

The dyes used in ancient times were derived from both vegetable and animal sources:

Red dye: Extracted from the madder plant.

Yellow dye: Obtained from the weld plant.

Indigo dye: Sourced from the indigo plant or woad.

The plant material was mashed in water, fermented, and then allowed to precipitate into blue indigotin dye. This precipitate was collected, dried, and sold in this form. For dyeing, the insoluble indigotin was converted into a soluble, colorless compound through a chemical treatment, such as using honey and lime. The fabric was soaked in this solution, and upon drying, the blue color developed due to exposure to air. This method is known as vat dyeing, where an insoluble dye is formed on the fabric after being soaked in a soluble precursor.

- The Royal Purple Dye: Tyrian Purple

One of the most prized dyes of ancient times was Tyrian purple, also known as royal purple. This dye, known today as dibromoindigotin, was highly valued for its rich, deep purple color. The dye was obtained from the glands of certain shellfish harvested from the Mediterranean Sea. The process involved extracting a nearly colorless precursor from the glands, which then developed into a purple color when the treated fabric was dried in the sun.

Other species of shellfish produced a violet dye, a mixture of indigotin and dibromoindigotin. The ancient dyeing industry was substantial, as evidenced by huge deposits of shells, all broken at a specific point to extract the dye precursor from the gland.

Ancient dye makers needed to reduce the colored compounds formed before the dyeing process. Pliny, a Roman author, describes how the dye extract was boiled in a vessel of tin (plumbum album). Tin and alkali helped reduce indigotin and dibromoindigotin to a colorless, soluble compound.

- Dyes in India

Varāhamihira’s Bṛhatsaṁhitā, from the 6th century CE, is an ancient encyclopaedia detailing how to make a sticky substance from plants, fruits, seeds, and barks for use on walls and roofs. This method, combined with resins, is thought to contribute to the long-lasting quality of ancient paintings in Ajanta and Ellora. Earlier texts like the Atharvaveda (1000 BCE) mention dyes made from turmeric, sunflower, madder, and others, while the Rigveda notes that leather tanning and cotton dyeing were practiced between 1000 and 400 BCE.

Paper in Ancient Times

The history of paper began in ancient China, where the first true papermaking process was developed during the Eastern Han period (25–220 AD). *Cai Lun*, a Chinese court official, is credited with inventing this process in 105 AD. He documented a method to produce paper using a combination of mulberry bark, plant fibers, fishing nets, rags, and hemp waste. This process was revolutionary because it reduced the cost and made paper more accessible for writing, drawing, and various other uses.

Before the invention of true paper, ancient civilizations used materials like papyrus in Egypt. Papyrus, made from the pith of the Cyperus papyrus plant, is not considered true paper because it was made by layering strips of plant material rather than breaking down fibers into a pulp. True paper, as developed in China, involves breaking down fibers to create a more even and durable surface. This technique allowed for smoother writing and better preservation of texts.

Papermaking technology spread from China to the Islamic world in the 8th century. By the 11th century, it had reached Europe, where it gradually replaced parchment and vellum, which were more expensive and labor-intensive to produce. In Europe, papermaking evolved further with the use of water-powered paper mills by the 13th century, particularly in Spain. This made paper production faster and more efficient.

- Paper in Ancient India

The history of papermaking in India is less clear due to the fragile nature of paper, which is easily destroyed by environmental factors or fungal and insect attacks. Only a few ancient specimens have survived, mostly in the protective environments of stupas or libraries. Manuscript evidence in eastern India starts from the 12th century, but there is earlier evidence of paper manuscripts with Indian scripts, likely of Indian origin, that have survived in the stupas of Kuchar in Central Asia and Gilgit in the Karakoram region. Based on palaeographic analysis, these manuscripts date back to the 5th and 8th centuries CE.

The Chinese traveler I-tsing recorded that paper was known in India by the 7th century. The Ashutosh Museum in Kolkata holds a paper manuscript dated to 1105 CE, which serves as one of the earliest physical pieces of evidence of paper use in India. Accounts from travelers who visited India between the 15th and 17th centuries also confirm that paper was not only used for writing but also for wrapping common goods.

Ink in Ancient Times

In ancient times, the invention and use of ink were closely tied to the development of writing and record-keeping across various civilizations. The materials and chemicals used to produce ink varied significantly depending on the resources available in different regions and periods.

- Egyptian Inks

One of the earliest known uses of ink was in ancient Egypt, where it was used for writing and drawing on papyrus. Egyptian inks were typically black or red. The black ink was made using soot (lampblack), collected from burning oil lamps, and mixed with a binding agent like gum arabic to help it stick to the papyrus. Red inks often contained ocher, a naturally occurring pigment made from iron oxide. Egyptian inks also contained ions such as phosphate, sulfate, chloride, and carboxylate, and sometimes lead was used to help the ink dry faster.

- Chinese Inks

The Chinese developed ink as early as four millennia ago during the Neolithic period. Early Chinese inks were made from natural substances like plants, minerals, and animals. The most common black ink was made from soot (also called lampblack) and animal glue, which was then ground with water to create a usable liquid ink. This ink was traditionally applied with a brush. Chinese inksticks, a solid form of ink, were also made from pine soot and fish glue. These could be ground with water on an inkstone to produce liquid ink. Over time, more refined inks were made for calligraphy and painting on paper or silk.

- Ink in Ancient India

Evidence suggests that ink was used in India from as early as the 4th century. An ink pot found during excavations at Taxila indicates the early use of ink. In India, ink colors were made from natural materials like chalk, red lead, and minium (Sindoor). The Rasaratnākara of Nityanatha, an ancient Indian text, provides recipes for making ink. Black ink, made from nuts and myrobalans, was known for its durability and was stored in iron pots filled with water, particularly in regions like Malabar. Jain manuscripts often used a special ink made from roasted rice, lamp black, sugar, and the juice of the plant kesurte. By the late medieval period, Indians were aware that a tannin solution turns dark blue-black or greenish when ferric salts are added. They applied this knowledge to make ink, similar to the iron gall inks used in Europe.

- Iron Gall Ink

In Europe, iron gall ink became the dominant writing ink from the 12th century onward. This ink was made from iron salts (like ferrous sulfate) combined with tannin, which was obtained from oak galls, and a thickening agent. Initially, it appeared dark blue-black on paper but gradually turned brown as it aged. While iron gall ink was valued for its durability, it is now known to be corrosive and can damage the paper over time.

- Roman and Cephalopod Inks

In ancient Rome, another type of ink called "atramentum" was used. This ink was made from soot, glue, and water, similar to some of the earlier Egyptian and Chinese inks. The Romans also used sepia ink made from the ink sacs of cephalopods like cuttlefish. Sepia ink was dark blue-black when wet but turned brown when dried.

Ancient inks were made from a wide range of natural materials, such as soot, minerals, plant extracts, and animal by-products, often mixed with binding agents like gum arabic or animal glue. In India, ink was made from materials like nuts, myrobalans, roasted rice, and plant juices, showing a rich diversity in ink-making practices. These inks were used for writing, drawing, and printing on materials like papyrus, parchment, and paper, and their formulations reflected the chemistry knowledge and resource availability of each culture.

Ayurvedic Medicine

Ayurveda is an ancient system of medicine that started in India and has a history going back to the 2nd century BC. It is based on the teachings of two Hindu philosophical schools, Vaisheshika and Nyaya, which focused on understanding a patient's condition through careful observation and logical reasoning. These schools combined their ideas to form the basis of Ayurvedic practices, emphasizing knowledge of both the patient and the disease. Ayurveda is closely linked to ancient texts called the Vedas, especially the Rig Veda and Atharva Veda, which mention various plants and how they can be used for healing. The Atharva Veda specifically talks about using plants and vegetables to treat diseases. Over time, two key texts of Ayurveda were developed: the *Charaka Samhita*, a comprehensive guide on medicine, and the *Sushruta Samhita*, a detailed work on surgery. These texts were written by ancient sages and scholars who gathered knowledge about the healing properties of plants and minerals in the form of poems, called "Shlokas."

Ayurvedic medicine is not only about using plants; it also explores the use of minerals and metals. Metals like mercury became very important in Ayurvedic treatments. In ancient Indian alchemy a wide range of natural substances, both organic and inorganic, were used for healing. Mercury, in particular, was highly valued. Before it could be used as a medicine, it had to go through 18 different purification processes, which shows an early understanding of chemical methods.

Ayurveda is based on the idea that the universe and the human body are made up of five elements: Air (Vayu), Water (Jala), Space (Aakash), Earth (Prithvi), and Fire (Teja). These elements combine in different ways to form the three main energies, or Doshas: Vata (Air and Space), Pitta (Fire and Water), and Kapha (Water and Earth). These energies control various bodily functions, and maintaining a balance between them is believed to be essential for good health. Imbalances can cause diseases, so Ayurveda aims to restore balance using natural treatments. Ayurveda also describes the body as made up of seven types of tissues, called Sapta Dhatus: Rasa (plasma), Rakta (blood), Mamsa (muscle), Meda (fat), Asthi (bone), Majja (marrow), and Shukra (reproductive tissue). Together with the three Malas (waste products: urine, feces, and sweat), these elements form the Ayurvedic understanding of the human body.

The combination of herbal medicine with treatments involving minerals and metals in Ayurveda marks an important point in the history of chemistry. Alchemical practices in Ayurveda involved changing and purifying materials, similar to the goals of Western alchemists who tried to turn base metals into gold or find the philosopher's stone. However, in Ayurveda, these processes were aimed at creating effective medicines rather than gaining wealth.

Alchemy

Alchemy is an ancient practice that combines elements of science, philosophy, and mysticism. It is considered the precursor to modern chemistry and medicine, aiming to transform materials and discover the secrets of life and the universe. Alchemy is a philosophical and proto-scientific tradition practiced throughout ancient and medieval times in different parts of the world. The word "alchemy" is derived from the Arabic term al-kimiya, which in turn was derived from the Greek word khemeia, meaning "art of transmutation."

Main Goals of Alchemy

The primary goals of alchemy included:

- Transmutation of Metals: The most famous goal was the transmutation of base metals, such as lead, into gold or silver. This pursuit was based on the belief that all metals were composed of the same basic substance, and by altering their properties, they could be transformed.
- Philosopher's Stone: Alchemists believed in a substance called the "Philosopher's Stone," which was thought to have the power to turn base metals into gold and grant immortality.
- Elixir of Life: The search for a universal medicine that could cure all diseases and grant eternal life was another significant goal.
- Spiritual Transformation: Alchemy was not just a physical science but also a spiritual and philosophical one. Alchemists aimed to achieve spiritual enlightenment and the purification of the soul, viewing the transformation of metals as a metaphor for human transformation.

Chinese Alchemy

Chinese alchemy is thought to be older than Western alchemy. Unlike in the West, where alchemy was closely tied to metallurgy (the study of metals), in China, it was connected to medicine. The Chinese believed in physical immortality as early as the 8th century BCE, and by the 4th century BCE, they thought it could be achieved through special drugs. One of these drugs was the "elixir of life," which was believed to make someone immortal. The most powerful elixir was "drinkable gold," a solution of gold that was mentioned as early as the 1st century BCE.

Alchemy in China grew during a time of political chaos called the Warring States Period (5th to 3rd century BCE). It became linked with Taoism, a mystical philosophy founded by Lao-tzu in the 6th century BCE, and its sacred text, the *Tao-te Ching* ("Classic of the Way of Power"). Taoist alchemists believed in using special substances to achieve immortality. One famous alchemical book is *Chou-i ts’an t’ung ch’i* ("Commentary on the I Ching"), which connected alchemy with the mystical ideas of an ancient Chinese text, the *I Ching*.

The first well-known Chinese alchemist was Ko Hung (283–343 CE). His book, *Pao-p'u-tzu*, contains recipes for making elixirs, often using mercury or arsenic. Another famous Chinese alchemical text is *Tan chin yao chüeh* ("Great Secrets of Alchemy"), likely written by Sun Ssu-miao (581–after 673 CE). It provides practical instructions for making elixirs for immortality and other purposes, like curing diseases. These elixirs often used ingredients like mercury, sulfur, and salts of mercury and arsenic.

Chinese alchemy focused mainly on creating elixirs for immortality, not on making gold or other medicines, as was more common in the West. The Chinese believed that the unreactive nature of gold made it a symbol of immortality, and they tried to make "alchemical gold" for this purpose. They even thought that eating food from plates made of this gold could prolong life.

Chinese alchemy remained consistent over time, with little conflict among its practitioners. Most disagreements were only about the ingredients or names of the elixirs. Unlike in Europe, where there were debates over herbal versus mineral remedies or gold-making versus medicine, Chinese alchemy always focused on the latter.

As Chinese alchemists continued to use poisonous substances in their search for immortality, many—including some emperors—died from these elixirs. Eventually, the dangers became too clear, and Chinese alchemy faded, especially as Buddhism, which offered safer paths to immortality, became more popular.

The idea of the "elixir of life" likely spread from China to other cultures, such as the Islamic world, through the Silk Road. The Chinese word for gold, "kim," might have even influenced the Arabic word "al-kimiya," which led to the European words "alchemy" and "chemistry."

Indian Alchemy (Rasayana and Rasaśāstra)

Indian alchemy, known as Rasayana or Rasaśāstra, is deeply rooted in Ayurveda, the ancient system of Indian medicine.

- Rasayana

Rasayana was one of the eight branches of Ayurveda which focuses on rejuvenation, restoring health, and promoting longevity. The term "Rasayana" is derived from the Sanskrit word "rasa," meaning "essence" or "juice". The concept of alchemy in India can be traced back to the earliest Indian writings, the Vedas. These ancient texts contain vague references to a connection between gold and long life, similar to those found in ancient Chinese alchemy. By the 4th-3rd century BCE, mercury, a key element in alchemy worldwide, was mentioned in the Artha-śāstra. Ideas of transforming base metals to gold also appear in Buddhist texts from the 2nd to 5th centuries CE, around the same time as in the West.

Alchemy in India saw significant development during the medieval period. Alchemy became more associated with religious mysticism during the rise of Tantrism (1100–1300 CE), an esoteric system that combined meditative and occult practices. One of the notable works from this period is the 12th-century Rasārṇava ("Treatise on Metallic Preparations"), which deals with metallic alchemy.

A prominent figure in Indian alchemy was Nagarjunacharya, who documented various alchemical processes in his work Rasaratanakaram. He conducted experiments in his laboratory, known as "Rasashala," focusing on transforming base metals like mercury into gold. Due to his expertise, he became the chancellor of Nalanda University, a renowned center of learning in ancient India.

The primary aim of Rasayana was to enhance rasa, the vital fluid in the body, to promote health, longevity, intelligence, memory, youthfulness, and other desirable qualities. It was believed to improve complexion, voice, strength, and mastery over language. The practice aimed not only at physical well-being but also at mental sharpness, sexual vitality, and even achieving extraordinary abilities.

Treatments in Rasayana often used special herbs preserved in ghee (clarified butter) and honey. Some key herbs used in Rasayana included haritaki, amla, shilajit, ashwagandha, holy basil, guduchi, and shatavari. Many classical formulations were developed in Rasayana, such as Amrit Rasayana, Brahm Rasayana, Jawahar Mohra, Laxmi Vilas Ras, Makaradhwaj Vati, and Navratna Ras. These formulations often contained a mixture of herbs, minerals, and other ingredients believed to have potent health benefits.

- Rasaśāstra: The Alchemy of Metals and Minerals

Rasaśāstra is a more specialized branch of Indian alchemy that deals with processes involving metals and minerals, especially mercury, which was thought to have transformative properties. Unlike Western alchemy, where metals were "resurrected," Indian alchemists "killed" metals (corroded them) to create medicines. The Indian alchemists were more focused on medicinal benefits and the creation of elixirs that could treat specific diseases and promote long life.

While Western and Chinese alchemists discovered mineral acids, Indian alchemists did not, despite having access to substances like saltpetre (potassium nitrate). Saltpetre was used in early recipes for fireworks and gunpowder in both India and China, but it was not employed in the same way for alchemical transformations as in the West.

The transmission of alchemical knowledge between India, China, and the West is possible, given historical interactions such as Alexander the Great's invasion of India in 325 BCE. However, while Western and Chinese alchemy placed significant emphasis on immortality and gold-making, Indian alchemy focused more on medicinal applications and enhancing longevity.

Alchemy in Alexandria (Greek-Egyptian Alchemy)

During the Hellenistic period, after Alexander the Great's conquests, Greek and Macedonian influence spread across the Middle East. When Alexander died in 323 BCE, his general Ptolemy established a kingdom in Egypt with Alexandria as its capital. The Ptolemaic dynasty set up the Museum and Library in Alexandria, which became important centers of learning.

In Alexandria, Greek ideas mixed with Egyptian chemical knowledge. Egyptians connected this knowledge to religious rituals and mummification. They believed that Thoth, the god of wisdom, was the source of all chemical knowledge. The Greeks, impressed by Egyptian knowledge, linked Thoth to their god Hermes and took in some of the mystical ideas. This blend created a special type of alchemy but also added secrecy and mystical elements that slowed down scientific progress.

Bolos of Mendes (around 200 BCE) is known for a book called Physica et Mystica ("Natural and Mystical Things"), which is like a recipe book for dyeing and coloring and mainly for making gold and silver. His work focused on changing metals, like turning lead or iron into gold. He believed that all materials could be changed from one to another. However, alchemists used mysterious symbols and secretive methods that slowed down sharing of knowledge and allowed fake alchemists to thrive.

Another important alchemist, Zosimus of Panopolis (around 300 CE), wrote about all the knowledge of alchemy from the past five or six centuries. He quoted from a text called On Furnaces and Apparatus, which described equipment and methods like the *water bath*. His works also talked about the process of "blackening, whitening, yellowing," which were steps believed to change substances into purer forms.

However, alchemy in Alexandria declined during the Roman period as Greek learning faded and mystical ideas increased. Emperor Diocletian ordered the destruction of alchemical writings because he feared cheap gold would harm the Roman economy. The rise of Christianity also suppressed "pagan" knowledge, causing much of alchemy to go underground. Yet, Greek alchemical knowledge was preserved by Nestorian Christians who fled to Persia in the 5th century.

Arabic (Islamic) Alchemy

Islamic alchemy, which evolved after the 7th century, played a significant role in preserving and extending Greek and Egyptian alchemical traditions. This period marked a turning point when Arabic scholars, inspired by the rise of Islam and their expanding empire, encountered and absorbed the scientific knowledge of the lands they conquered.

Before the advent of Islam, the Arabian Peninsula was relatively isolated. However, after the founding of Islam by Prophet Mohammed, the Arabs rapidly expanded their territories across Western Asia, Northern Africa, and beyond. By 641 AD, they had conquered Egypt, and soon after, Persia. In Persia, they encountered the remnants of Greek science and became deeply interested in it. This newfound interest was further intensified by their encounters with "Greek fire" during the siege of Constantinople in 670 AD—a mysterious chemical weapon that could not be extinguished with water.

The word "alchemy" itself comes from the Arabic term al-kimiya, derived from the Greek word khemeia. The prefix "al" means "the" in Arabic, and the term was adopted into European languages as "alchemy." Alchemists, as those who practiced this art were called, were engaged in a range of chemical experiments that formed the basis for modern chemistry.

From about 650 AD onwards, Greek-Egyptian alchemical knowledge was preserved and further developed by the Arabs. This period lasted for around five centuries and produced many key figures and developments in the field. The influence of Islamic alchemy is still evident today in many chemical terms derived from Arabic, such as alembic, alkali, alcohol, carboy, naphtha, and zircon.

The early period of Islamic alchemy saw the emergence of some of its most renowned scholars:

- Jabir ibn-Hayyan (c. 760–c. 815)

Known to later Europeans as "Geber," Jabir is considered one of the greatest Muslim alchemists. He lived during the height of the Islamic empire under Caliph Harun al-Rashid. Jabir's writings were numerous, and although some works attributed to him may have been written by others, his contributions were substantial. He described how to prepare chemicals like ammonium chloride and white lead, and he distilled vinegar to produce strong acetic acid, which was among the most potent acids known to the ancients. He even managed to create weak nitric acid. Jabir's most notable work was on the transmutation of metals. He theorized that metals were made up of different combinations of two basic elements: mercury (which he believed represented fluidity and purity) and sulfur (representing combustibility and the yellow color of gold). He sought to find a substance that could combine these elements in the right proportions to create gold. This substance was referred to as the "elixir" (from the Arabic al-iksir) or the "philosopher's stone"—a legendary material believed to turn base metals into gold and grant immortality.

- Al-Razi (c. 850–c. 925)

Following Jabir, Al-Razi, known to Europeans as "Rhazes," was another significant alchemist and physician. He made notable contributions to chemistry and medicine, describing substances like plaster of Paris and its use in setting broken bones. He also studied metallic antimony and expanded on Jabir's ideas by adding a third principle—salt—to mercury and sulfur, to explain the composition of solids. Al-Razi leaned more towards the medical aspects of alchemy, which influenced later developments in the field.

- Ibn Sina (979–1037)

Better known in the West as "Avicenna," Ibn Sina was one of the most prominent physicians between the Roman Empire and the rise of modern science. Although he was involved in alchemy, he was skeptical about the possibility of turning base metals into gold. He is a rare example of an alchemist who doubted the traditional beliefs of alchemy, setting him apart from his contemporaries.

Islamic alchemy was instrumental in preserving and expanding ancient scientific knowledge. It introduced new concepts, techniques, and chemicals, paving the way for modern chemistry. While the search for gold and immortality was never realized, the contributions of Islamic alchemists like Jabir ibn-Hayyan, Al-Razi, and Ibn Sina laid the groundwork for scientific methods and discoveries that followed.

During the Islamic Golden Age, alchemy developed along two primary paths:

Mineralogical Alchemy: Focused on transmuting base metals into gold.

Medical Alchemy: Sought to create a universal cure (the "elixir of life") that could heal all diseases and potentially grant immortality. Arabic science declined quickly after the time of Avicenna. The Islamic world faced increasing instability, which worsened due to the invasions and military successes of the Turks and Mongols. After three centuries, the Arabs lost their position as leaders in science, and this leadership shifted to Western Europe.